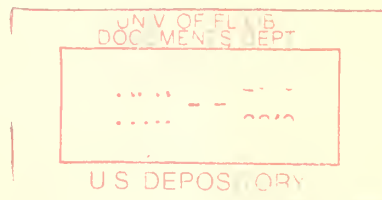


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U. S. Department of Agriculture, Forest Service
FOREST PRODUCTS LABORATORY

In cooperation with the University of Wisconsin

MADISON, WISCONSIN



THE FOREST PRODUCTS LABORATORY

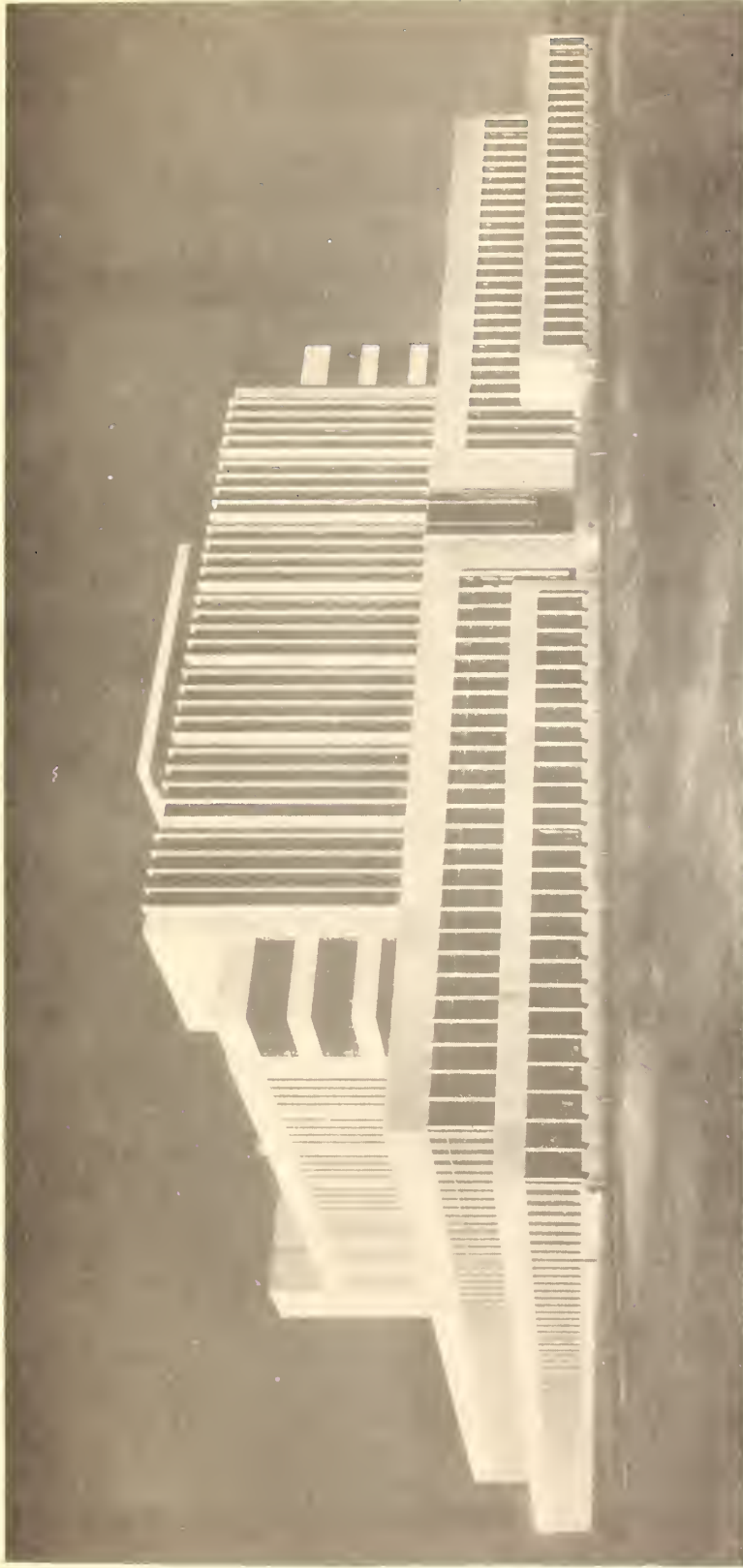
By F. J. CHAMPION
Assistant Technical Writer

April, 1932



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HOLABIRD & ROOT - ARCHITECTS

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The new Forest Products Laboratory building, completed in October 1932.

THE FOREST PRODUCTS LABORATORY¹

By
F. J. Champion

Research in forest products is a vital element in any farsighted job of forest administration. Its aim is maximum efficiency in using existing and projected forest stands and adapting them to the changing needs of the nation. This general purpose guides the work of the Forest Products Laboratory at Madison, Wis., a part of the U. S. Forest Service.

The Laboratory was established in 1910 -- just five years after the present Forest Service was organized in the Department of Agriculture. At that time no other nation -- however old in the practice of forestry -- was engaged in any comprehensive program of research in forest products. Under a cooperative arrangement the University of Wisconsin erected the Laboratory building and agreed to contribute light, heat, and power to the maintenance of Laboratory operation.

Organization

At present the Forest Products Laboratory is organized for research on (1) growth of wood as it affects its properties and ultimate utility, (2) logging and milling practices, (3) selection and preparation (grading, seasoning, etc.) of wood for use requirements, (4) internal and surface treatment of wood, (5) mechanical adaptation of wood to construction and fabrication, and (6) conversion of wood into pulp and paper. For purposes of administration these lines of research are carried on by a slightly greater number of Laboratory sections, viz., the sections known as Silvicultural Relations, Timber Physics, Timber Mechanics, Industrial Investigations, Wood Preservation, Derived Products, and Pulp and Paper. An office of Forest Pathology is maintained at the Laboratory by the Bureau of Plant Industry, Department of Agriculture. A section for Operation administers personnel, quarters, and materials, and the section called Publication of Results serves the purpose its name would indicate.

¹This paper was prepared for publication in The Military Engineer.

Growth Studies

In view of the keen competition of other structural materials it is plain that not only must wood be adapted to use requirements by proper selection of species and quality and proper seasoning, but also it must in many cases be grown with a specific use in mind. One of the functions of the Forest Products Laboratory's section of Silvicultural Relations is to determine the effect of various site conditions such as soil, precipitation, and spacing, in the forest stand upon the physical properties of wood. The spacing factor, both as a part of planting operations and as controlled by thinning practices, is extremely important in the production of wood having predictable and desirable properties. It has been found, for instance, that in southern pine the conditions productive of dense, strong wood for structural purposes are a moist site, close spacing in the stand, and protection from fire. On the other hand, in the same species, light-weight wood of moderate strength suitable for less exacting requirements -- say pulping -- can be produced mainly by open spacing of the stand, together with adequate fire protection.

In contrast to the growth of conifers, which tend to produce their strongest, heaviest wood in relatively close stands, hardwoods produce their strongest material when sustained or increasingly rapid growth occurs in open stands or as the result of tinnings.

Naval Stores Work

The determination of growth-strength relations is but one function of the section of Silvicultural Relations. This section is engaged in studies of the production of turpentine and rosin from the southern pines, with results of considerable significance to date. It has been found that the cutting of a weekly streak or only one-quarter inch high at the top of the usual turpentine "face" is in the long run fully as productive of the raw material, oleoresin, as a streak one-half or even three-quarters inch high. The advantage of thus providing for a number of years' additional leasing period for the trees is obvious. This doctrine, as well as the Forest Service policy of working only trees 8 inches in diameter and larger is now being steadily incorporated into woods practice in the main naval stores regions of South Carolina, Georgia, and Florida.

Wood Identification

Many species of wood may be identified as readily by minute cell structure as by the botanical characteristics of the living tree. The Silvicultural Relations section of the Forest Products Laboratory is official government headquarters for wood identification on this basis. Largely originating in controversies incident to the marketing of forest products of all kinds, about 3,000 wood samples per year come to the section for an authoritative identification. Frequently costly litigation hinges upon the result of an examination of sawdust, wood flour, or a few slivers.

Wood Seasoning

The Forest Products Laboratory's section of Timber Physics is concerned with seasoning, an extremely important factor in the success of wood as either structural or finish material. Both air seasoning and drying in kilns are studied. The section has worked out the basic principles involved in drying the various classes of lumber ranging from the lowland hardwoods to the least refractory of the softwoods. Special studies on major commercial species are being carried on and published as rapidly as the program will permit. The aim of kiln drying schedules is, of course, rapid elimination of surplus moisture -- the cause of shrinking and swelling and decay -- without the introduction of checks, warping, kiln stain, and other effects of badly tempered drying.

Although the general principles of ventilation and yard sanitation for the successful air seasoning of wood have been widely disseminated by the Laboratory, recent surveys indicate that in general the conditions of yarding, storage, and shipment are operating to the disadvantage of wood in many parts of the country and that there is urgent need for extension of good practice to correct a most unfortunate situation.

One of the main obstacles to the proper control of moisture content in lumber has been the lack of any means of determining moisture content by other than slow and not especially satisfactory methods. This obstacle has been removed by the Forest Products Laboratory with the recent invention of an electrical moisture-content meter that is simple, portable, economical in construction and operation, and accurate to 1 percent. Its effective range (7 to 34 percent) corresponds closely to the range of wood moisture content that is most critical in use. This instrument, called



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Test of a built-up beam with glued laminations. Modern wood research looks to the more effective production and utilization of composite members.

-the "blinker" because of the two flashing neon bulbs that indicate relative wetness or dryness, is now being manufactured and sold commercially.

A study of the moisture content range in various parts of dwellings in five distinct climatic regions of the United States has yielded information on optimum moisture content for the installation of wood in dwellings. The findings will be released soon to contractors, millwork manufacturers, furniture makers, and others concerned with the proper seasoning, handling, and use of wood in relation to climatic conditions.

Strength Studies

A large and important section of the Laboratory is the section of Timber Mechanics. Over 60 percent of the lumber produced in the United States is used in building construction, about half going to the farm and half into urban residences and industrial buildings. In this highly competitive field, accurate strength data on wood and its structural combinations is essential. Wood has lost much ground to other materials because of antiquated methods of design and rule-of-thumb specifications.

To meet the need for strength data the Forest Products Laboratory mechanics laboratory has carried out tests since 1910 that have made it possible to publish complete information on the strength, weight, and shrinkage of no less than 164 native woods. These data, embracing the results of tests of compression parallel to grain, static bending, impact bending, compression perpendicular to grain, hardness, shear parallel to grain, cleavage, tension perpendicular to grain, tension parallel to grain, shrinkage, and specific gravity, have been made on small, clear specimens of both green and air-dry wood. In addition to these tests, much work has been and is being done on timbers in structural sizes, and special equipment and personnel have been devoted to the working out of the engineering principles involved in the construction of wooden containers, aircraft members, and recently, frame buildings.

Fundamental principles of box and crate construction have been worked out with special equipment including a vibrating table and a 14-foot box-testing drum capable of testing boxes up to 1,500 pounds in weight and 4 feet in cube, as well as by standard compression and drop tests. The results



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The 14-foot box drum, in which thousands of shipping containers have been tested to establish the principles of efficient, economical design and nailing.

of this research have been published in a complete manual. The problems of transportation hazards of car movement have been attacked, with results that have shown the way to shipping agencies entering on intensive studies in this field.

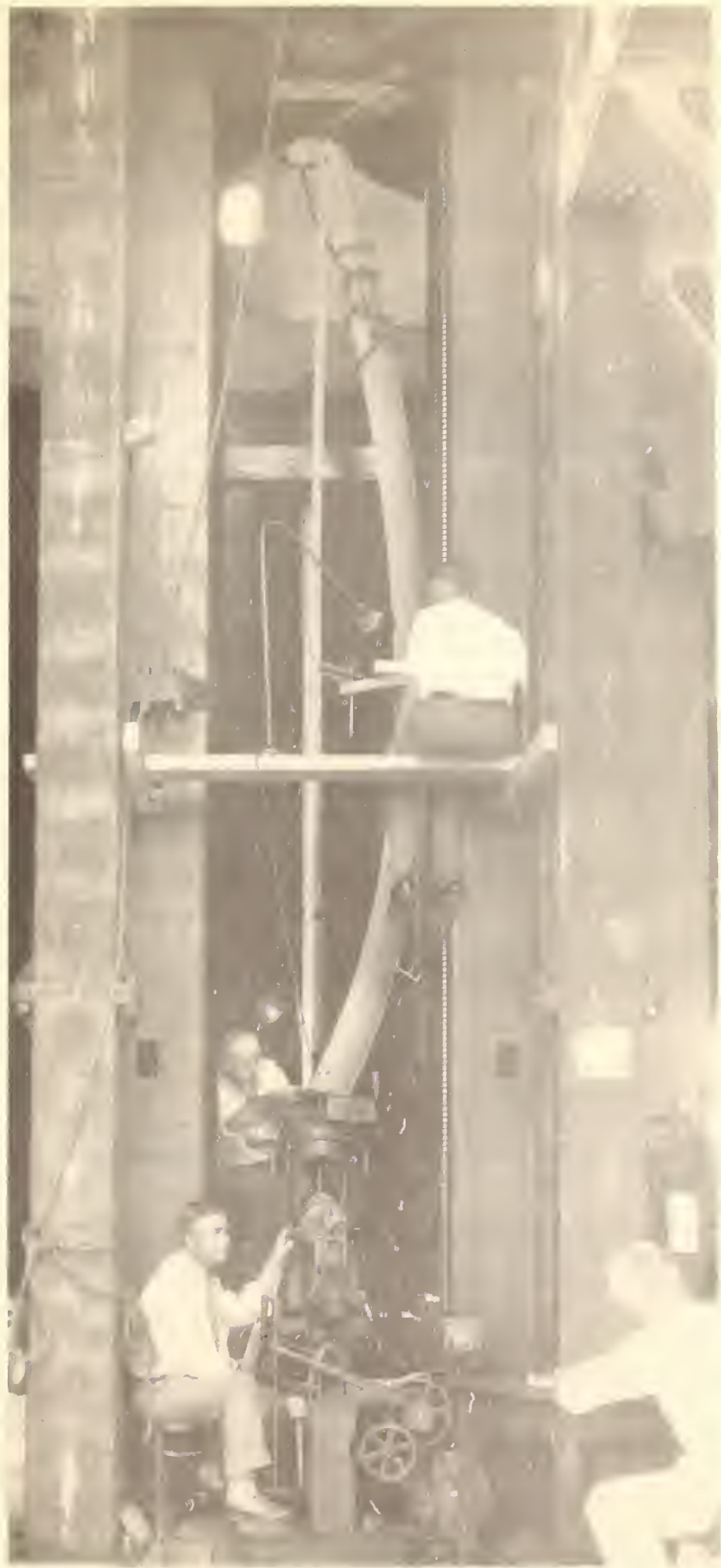
By means of full-scale tests on typical wall panels, made possible in part by a million-pound testing machine, it has been possible for the Laboratory to indicate elementary means of sheathing and bracing to increase the rigidity of house walls by as much as 400 percent above that currently obtained. The tests were prompted in part by examination of buildings affected by severe storms in various parts of the United States.

The studies of the use of wood in aircraft, undertaken during the late war, gave birth to several of the Forest Products Laboratory's main lines of research. This subject was dealt with by G. W. Trayer in an article in The Military Engineer for November-December, 1929.

Typical of the Forest Products Laboratory's researches in the engineering use of wood were the recently concluded tests of the design of bolted and fish-plated timber joints on Douglas fir, southern pine, spruce, oak, and maple fastened with steel bolts of diameters up to one inch. Since disastrous failures of wood construction often occur as a result of faulty jointing, the engineering value of this study is obvious. In so simple a question as the strength in tension of a single-bolted joint in wood, engineering handbooks give data varying by as much as 600 percent. As a result of the tests, the allowable stress in joints in direct tension or at any angle with the grain of the wood can be calculated from the diameter, length, and number of bolts. Steel fish plates replacing wood cleats were found to increase the efficiency of joints 25 percent.

Logging and Milling Studies

The section of Industrial Investigations is concerned with the economics of small sawmill and logging operations, the use of ready-cut (small-dimension) stock by industries, the refinement of grading practices, and the utilization of neglected species. Up to a few years ago when the passing of the virgin timber became a reality and the short or continuous crop operation of forests began to be talked about the lumbermen, however thrifty, had little information on the actual costs of handling trees and logs of



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Testing a laminated wood arch for deflection and maximum end load.

various diameter classes and grades. The section of Industrial Investigations has developed this type of information for the Lake States, Appalachian, Arkansas, California, and Coastal Plains regions. For example, it has been found that in the second-growth shortleaf and loblolly type of the southern pine forest region, every thousand feet of lumber cut from trees 10 inches in diameter a loss of \$3.29 is incurred, not including stumpage, as compared to a profit of \$11.73 for 24-inch trees.

In recently inaugurated studies of the small sawmill -- an important economic unit in some forest regions -- it has been found that the operators ordinarily ignore items amounting to some \$2.50 per thousand board feet or from 9 to 22 percent of the total cost, and that the yield of salable lumber can be increased by as much as \$1.60 per thousand by greater-than-usual care in adjustment of the mill setworks. This information is being extended to the small operator largely through state or local agencies.

Special compilations of the strength and utilization data of several neglected tree species, notably aspen, western larch, and western hemlock have been undertaken recently, largely on the basis of data already available but not hitherto exploited. The collected information is being released to the public as rapidly as possible in the form of Department of Agriculture technical bulletins.

Preservative, Paints, and Accessory Materials

One of the most productive fields in which forest products research has been engaged is the modifying of wood properties through the use of chemical preservatives (such as creosote and zinc chloride), paints and coatings, fire retardants, and glues. This is the province of the section of Wood Preservation. The section has taken a leading part in the development of an art -- wood treating -- already well established in industry. Through an increasing amount of use of treated ties a representative group comprising about half the railroads of the United States has in the last twenty years reduced average tie replacements from nearly 250 per mile of track per year to about 180 per mile of track per year. The actual saving to all railroads through tie treating is estimated at \$145,000 per day. In addition to experimental impregnation work, the Laboratory exercises leadership in the field of wood preservation in acting as headquarters for service records of over a million railroad crossties



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The Laboratory has set up paint test fences for observation in eleven climatic regions of the United States.

and a large number of posts, poles, etc., treated and untreated, that are in service (and hence undergoing the most conclusive and satisfactory possible test of durability) all over the United States.

In the field of fire-retardants the Forest Products Laboratory has developed a standard test for inflammability of wood that is now accepted by leading testing agencies. The Laboratory is using the special apparatus and technic in an extensive and thorough examination of chemicals for making wood resistant to fire.

In the same section the only comprehensive researches on the gluing of wood in this country have been carried on. The principles involved in proper interrelation of glue viscosity, temperature, assembly time, and pressure have been worked out so that joints as strong as the wood itself or stronger can regularly be obtained by scientific glue-room practice with all but the most refractory woods. The technic of gluing plywood has been highly developed and recently a chemical treatment has been devised for blood albumin glue that has protected plywood joints from any appreciable loss of strength through decay in a moisture-saturated atmosphere for five years.

As a result of seven years of exposure tests of 15 species of wood on eleven test "fences" in various climatic regions of the country, the section of Wood Preservation has been able to group the common woods with respect to painting qualities and to lay the groundwork for real development of paints and coatings for wood.

Chemical Studies

The Forest Products Laboratory's section of Derived Products is engaged mainly in fundamental studies of the chemistry of cellulose and lignin, the most important chemical constituents of wood. Although cellulose is used daily in the production of pulp, paper, lacquers, rayon, and viscose and is skillfully controlled within the limitations of the various processes, little enough is known of its exact chemical nature. The extension of chemical conversion to forest thin-nings, unused species, and logging wastes will necessarily come, not through chance discovery but through a clearer knowledge of cellulose and its chemical relationships.



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Research on fire-resistant treatments of wood.

Lignin is relatively new on the Derived Products section's research program. The substance is the bete noir of practically all processes for refining cellulose and yet practically all that is known or suspected about it is that it has several marked points of similarity to cellulose. Lignin may prove to be as ugly chemically as its history to date would indicate but it is hoped that it will repay better acquaintance.

The Derived Products section is also engaged in studies of the extractives -- the free water-soluble substances found in some woods -- and in studies of the toxicity to decay organisms of various chemicals. The latter study is a part of the search for the "perfect" preservative -- that is, one that is cheap, toxic to fungi, but not too much so to live stock, non-corrosive, non-leaching, etc.

Pulp and Paper Studies

The Forest Products Laboratory's Pulp and Paper section carries on studies calculated to improve existing pulping and paper-making methods, to produce new methods, and to extend the benefits of various methods to hitherto neglected but abundant species, and to various mill and industrial and wood wastes. Notable success has been attained in widening the outlets for the southern pines. Originally producing only kraft papers these woods, it is known now, can be used in the production of book, writing, grease-proof, glassine, and other economically important papers. An entirely new process -- combining the desirable attributes of both chemical and mechanical pulping -- was devised to produce high yields of cheap print paper from both hardwoods and softwoods. This process, involving the use of the rod mill -- a device borrowed from the metallurgical industries -- has been installed in numerous pulp and paper mills. The Pulp and Paper section is now extending its researches intensively to the western woods, particularly to western mill wastes.

War Activities

Like many an individual the Forest Products Laboratory found the late war to be the greatest single stimulus of its history and the greatest test of its worth to the Nation. When war was declared the Laboratory was



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Charging an experimental digester with pulping chips. Efficient conversion of a great variety of American wood species into pulp and paper products of good quality is needed to solve the problem of the Nation's permanent pulpwood supply.

certain that its services would be needed, but was a little vague as to just where to inaugurate work that would help to win the war. The indecision was not of long duration. Officers of both Army and Navy soon became aware that the Laboratory was the proper reference point for many of materials problems and the Laboratory was overwhelmed with requests for wood utilization information that demanded answers "at the earliest possible moment." Between June, 1917, and November, 1918, it was necessary to increase the force from 85 to 450 and to operate on a three-shift basis.

Seventy to 75 percent of the Laboratory's war work pertained to aircraft. When the United States entered the War the greater part of the production of airplane spruce had already been contracted for by the British, French, and Italian governments. At the same time aircraft engineers were not ready to accept kiln dried material. The Forest Products Laboratory developed a successful kiln-drying schedule for three-inch airplane spruce plank that seasoned the material in from 20 to 45 days instead of the one to two years required for air seasoning.

When the Spruce Production Division was organized in the Signal Corps, the Laboratory was called upon to design dry-kiln equipment. Twenty-four kilns designed by the Laboratory dry-kiln specialists operated successfully with a daily output of 40 thousand board feet of wing material per day from July, 1918, until the end of the war.

Tests of plywood inaugurated at the Laboratory in connection with aircraft production form the basis of all present water-resistant plywood specifications used in airplane design in both Army and Navy. War work on both the gluing and moisture proofing of wooden propellers gave birth to the present Forest Products Laboratory glue laboratory and led to the discovery of the preeminence of aluminum leaf and aluminum powders for moisture-excluding coatings.

During the war and in winding up studies then started the field of wood use in aircraft has been much more fully investigated than has the use of metals in the same industry.

Demands of the Ordnance Department made it necessary for the Forest Products Laboratory to inaugurate the container testing division that functions for the benefit of industry today. Problems that were solved included those pertaining to the design of a cargo-space-saving packing case for Browning Automatic rifles, and wooden containers for marmites, hand grenades, high explosives, shells, and artillery harness.

Miscellaneous tests that are recorded in the Laboratory's reports had to do with the strength of cannon ramrods, proper handles for intrenching tools, wooden dunny noses used in the shipment of shrapnel shells, the development of new species of wood for wooden-ship treenails, and the development of reliable sources for gas-mask absorptive charcoal.

After the Armistice the Laboratory staff was reduced to somewhere near its present strength of about 200 persons.

Cooperative Research

The Forest Products Laboratory research program is supported by Congressional appropriation and planned on a long-time basis to meet and anticipate both the needs of industry and the needs of the men administering the national forests. No routine testing is undertaken, but occasionally researches are undertaken on a cooperative basis when a large group of individuals or an entire industry seems likely to benefit. In such cases the cooperating firm, individual, or agency pays from 50 to 100 percent of the actual costs incurred in the research.

Publications

The Forest Products Laboratory has published its findings regularly in the form of Department of Agriculture bulletins, circulars, and leaflets, and in less formal mimeographed and multigraphed reports and technical notes. The publications section will gladly supply a list of publications pertaining to any research section or group of sections, and will place qualified individuals on its mailing list to receive a semi-annual list of publications or publications of a specified topic. A few of the Laboratory's publications are as follows:

"Guidebook for the Identification of Woods Used for Ties and Timbers," U.S. Forest Service, 30 cents.

"Comparative Strength Properties of Woods Grown in the United States," U.S.D.A. Technical Bulletin 158, 10 cents.

"Kiln Drying Handbook," U.S.D.A. Bulletin 1136, 30 cents

- "Mechanical Properties of Woods Grown in the United States,"
U.S.D.A. Bulletin 553, 10 cents.
- "Properties of Western Hemlock and Their Relation to Uses of
the Wood," U.S.D.A. Technical Bulletin 138, 20 cents.
- "Tests of Large Timber Columns and Presentation of the Forest
Products Laboratory Column Formula," U.S.D.A. Technical
Bulletin 167, 15 cents.
- "The Gluing of Wood," U.S.D.A. Bulletin 1500, 25 cents.
- "Principles of Box and Crate Construction," U.S.D.A. Technical
Bulletin 171, 55 cents.
- "The Air Seasoning of Wood," U.S.D.A. Technical Bulletin 174
35 cents.
- "Gluing Wood in Aircraft Manufacture," U.S.D.A. Technical
Bulletin 205, 25 cents.
- "Kiln Drying of Southern Yellow Pine Lumber," U.S.D.A.
Technical Bulletin 165, 20 cents.
- "Effectiveness of Moisture-Excluding Coatings on Wood,"
U.S.D.A. Circular 128, 10 cents.
- "Decays and Discolorations in Airplane Woods," U.S.D.A.
Bulletin 1128, 20 cents.
- "The Preservative Treatment of Farm Timbers," Farmers'
Bulletin 744, 5 cents.
- "Control of Decay in Pulp and Pulpwood," U.S.D.A. Bulletin
1298, 25 cents.
- "Suitability of American Woods for Paper Pulp," U.S.D.A.
Bulletin 1485, 20 cents.
- "Properties of Western Larch and Their Relation to Uses of
the Wood," U.S.D.A. Technical Bulletin _____, _____cents.

The above publications may be obtained from the
Superintendent of Documents, Government Printing Office,
Washington, D. C., at the prices indicated.

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